and M_1, M_2 are the coefficients of mutual induction of the circular ends of the sheet and the helix.

Hence the calculation of this force reduces itself to a double application of the formulæ for the coefficient of mutual induction of a circle and coaxial helix.

It is hoped that this may form a useful method of calculating the constant of current weighers designed to measure current in absolute units.

"A Note on some further Determinations of the Dielectric Constants of Organic Bodies and Electrolytes at very Low Temperatures."

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In several previous communications* we have described the investigations made by us on the dielectric constants of various frozen organic bodies and electrolytes at very low temperatures. In these researches we employed a method for the measurement of the dielectric constant which consisted in charging and discharging a condenser, having the given body as dielectric, through a galvanometer 120 times in a second by means of a tuning-fork interrupter. During the past summer we have repeated some of these determinations and used a different method of measurement and a rather higher frequency. In the experiments here described we have adopted Nernst's method for the measurement of dielectric constants, using for this purpose the apparatus as arranged by Dr. Nernst which belongs to the Davy-Faraday Laboratory. The frequency of alternation employed was 350 or thereabouts, whereas in all our formerly described experiments with the galvanometer method it was 120.

The electrical details of the arrangement employed in Nernst's method are as follows:—A Wheatstone's bridge is formed (see diagram), two sides of which consist of variable resistances, R_1, R_2, which are usually liquid resistances contained in U-tubes. The other two sides of the bridge consist of two sliding condensers of variable capacity, C_1, C_2, which are shunted by adjustable liquid resistances, R_3, R_4. The bridge circuit contains a telephone, T, as detector. The alternating currents are furnished by an induction coil, I. An experimental condenser, X, the dielectric of which can be made

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* See Fleming and Dewar, 'Roy. Soc. Proc.' (1897), vol. 61, pp. 2, 299, 316, 358, 368, and 381.

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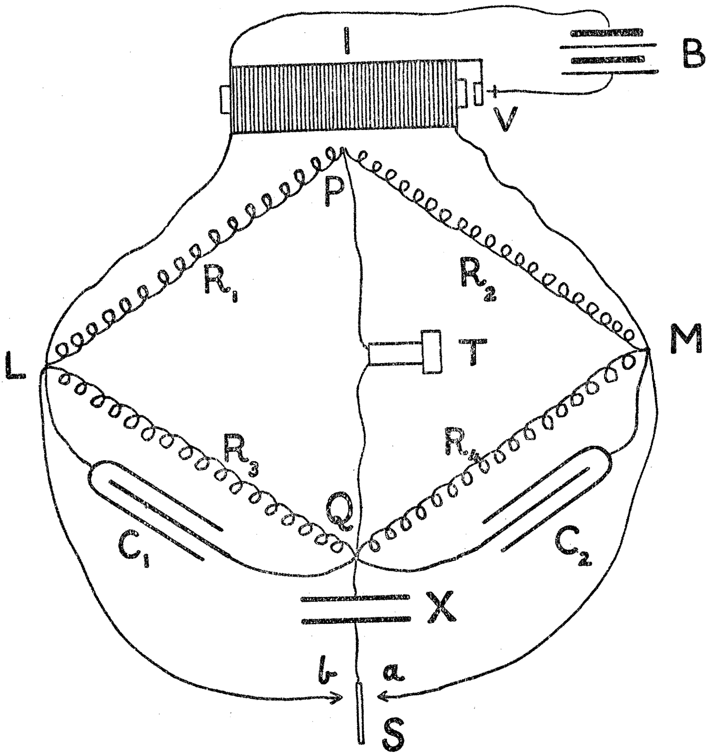

to be the substance under examination, is connected, as shown in the diagram, so that it can be placed in parallel with either of the shunted condensers forming the third and fourth arms of the bridge. The process of measurement is then as follows:—The experimental condenser is placed in parallel, by the switch S, say, with the third arm of the bridge, and the shunt resistances are first adjusted, so that the telephone gives a minimum of sound. The capacity of one sliding condenser, C_1, is then varied until complete silence in the telephone in the bridge is obtained. The experimental condenser is next shifted over into parallel with the fourth arm, and the capacity of the same sliding condenser is again adjusted to produce silence in the telephone. The change in capacity thus made in the sliding condenser corresponding to the change in position of the experimental condenser is denoted by s. The experimental condenser then has its air dielectric replaced by a liquid of known dielectric constant D_0, and the same process of change of its position effected. Let the variation of the adjustable sliding condenser then be denoted by S_0. Finally the experimental condenser has its air dielectric replaced by a liquid or frozen liquid of unknown dielectric constant D, and the process of change and adjustment a third time repeated. Let the variation of the sliding condenser in this third case be S. It is then very easy to show that the following relation holds good between D_0, D, S_0, S, and s, viz. :—

$$\frac{D_0-1}{S_0-s}=\frac{D-1}{S-s}$$

or

$$D=\frac{D_0-1}{S_0-s}(S-s)+1.$$

In order to apply this method we employed absolute ethylic alcohol as the standard dielectric substance of known dielectric constant, and took as its dielectric constant at 15° C. the value 25·8 (according to Nernst), a number closely in agreement with all the best results by other observers.

The actual capacity of the experimental condenser with air as dielectric was very small, not being more than about 0·00001 of a microfarad. Hence in the above formula $D_0 = 25{\cdot}8$.

The value of s was determined to be 1·33 and 1·38 in two experiments, and the mean 1·36 was taken as the value of s.

The following liquids were then examined by placing them in the experimental condenser and keeping them at ordinary temperatures, viz., 16° C. to 20° C.

1. Solution of Potassic Hydrate in water, 5 per cent. solution.
2. Solution of Rubidic Hydrate in water, 5 per cent. solution.
3. Amyl alcohol.
4. Ethylic ether.
5. Ethylic ether, pure and dry.
6. Ethylic alcohol.

The change in capacity of the sliding condenser when ethylic alcohol replaced the air in the experimental condenser was 16·7. Hence $S_0 = 16{\cdot}7$ and $D_0 = 25{\cdot}8$, also $s = 1{\cdot}36$.

Therefore

$$\frac{D_0-1}{S_0-s}=\frac{24{\cdot}8}{15{\cdot}34}=1{\cdot}613.$$

The following table shows the observed values of s in the several cases when the above liquids were placed in the experimental condenser, and the corresponding calculated value of the dielectric constant D, where $D = 1{\cdot}613\times(S-s)+1$.

Table I.—Determinations of the Dielectric Constants of certain Liquids at Ordinary Temperatures (15° C.) by Nernst's Method. Frequency = 320.

Substance.	S.	S − *s*.	1·613 (S − *s*).	Dielectric constant = D.
Ethylic alcohol (taken as the standard of comparison)	16·7	15·34	24·8	25·8 (assumed value)
Amyl alcohol	10·49	9·13	14·7	15·7 (calculated)
Ethylic ether........	3·98	2·62	4·23	5·23 (calculated)
Pure dry ethylic ether	3·70	2·34	3·78	4·78 (calculated)

Hence by Nernst's method, assuming the dielectric constant of ethylic alcohol to be 25·8, we find that of amyl alcohol to be 15·7 and pure ethylic ether to be 4·78.

Nernst himself found amyl alcohol to be 16·0 and ethylic ether to be 4·25 at about this temperature. Hence our values are in fair agreement with his.

In the next place we cooled the experimental condenser down to the temperature −185° C. in liquid air, after filling it with one of the above six dielectric liquids, and we repeated all the above-described operations again. The results are collected in Table II.

Table II.—Determinations of the Dielectric Constants of certain Frozen Liquids at the Temperature of Liquid Air by Nernst's Method. Frequency = 320.

Substance.	S.	S − *s*.	1·613 × (S − *s*).	Calculated dielectric constant = D.
Ethylic alcohol	2·68	1·32	2·13	3·13
Amyl alcohol	2·34	0·98	1·58	2·58
Ethylic ether	2·16	0·80	1·29	2·29
5 per cent. solution of Rubidic Hydrate	2·94	1·58	2·55	3·55
5 per cent. solution of Potassic Hydrate	5·15	3·79	6·12	7·12

The above values for the organic bodies are in close agreement with the results we obtained for the same substances by the galvanometer and switch method formerly used by us, as may be seen by a reference to Table III.

Table III.—Comparison of the Determinations of certain Dielectric Constants made by different Methods at the Temperature of Liquid Air.

Substance.	By galvanometer and switch method. Frequency = 120. Dielectric constant.	By Nernst's bridge method with telephone. Frequency = 320. Dielectric constant.
Ethylic alcohol	3·11	3·13
Amyl alcohol	2·14	2·58
Ethylic ether	2·31	2·29
5 per cent. solution (aqueous) of Potassic Hydrate	123·0	7·12
5 per cent. solution (aqueous) of Rubidic Hydrate	81·6	3·55

The results collected in the above Table III, show that the two methods give practically identical values for the two alcohols and the ether, but very different value for the two frozen dilute hydrates

An examination was then made of several other substances, and for this purpose another condenser was constructed, which consisted of a platinum crucible about 4 cm. in diameter and 5 cm. high. This crucible was fitted with an ebonite lid, through which passed a glass test-tube, in the interior of which was placed our platinum thermometer. Round the outside of the test-tube, platinum wire was closely wound, so as to form the opposed surface of a condenser in relation to the platinum crucible as the other surface. This platinum condenser could then be filled with any electrolyte or organic liquid and frozen in liquid air.

Owing to the very small actual capacity of this last experimental condenser, and especially that of the variable part of it in comparison with the capacity of the leads and connections, no very great accuracy of measurement was looked for or attained. The results, however, were sufficient to check the general [accuracy of the experiment with similar substances by the galvanometer method. This platinum condenser was calibrated and used with the Nernst bridge, exactly as in the previous experiment.

With the experimental condenser empty the change in capacity of the variable sliding condenser in the bridge arm was 1·50 on changing over the position of the experimental condenser. Hence $s = 1{\cdot}50$.

When filled with ethylic alcohol ($D_0 = 25{\cdot}8$) the change of capacity of the sliding condenser was 6·20. We have, therefore, $S_0 = 6{\cdot}20$, $D_0 = 25{\cdot}8$, $s = 1{\cdot}50$.

Therefore
$$\frac{D_0 - 1}{S_0 - s} = \frac{24{\cdot}8}{4{\cdot}70} = 5{\cdot}27.$$

The experimental condenser was then filled with some liquid, either at ordinary temperature or frozen at a low temperature, and the bridge measurement made, and the reading S or the change of capacity of the sliding condenser observed, as before, when the experimental condenser had its position changed.

The following Table IV gives the summary of the results obtained with several substances at various temperatures.

Table IV.—Measurement of the Dielectric Constants of various Substances at different Temperatures by Nernst's Method. Frequency = 320. $S = 1{\cdot}50$, $\frac{D_0-1}{S_0-s} = 5{\cdot}27$.

Substance.	S.	S − *s*.	5·27(S − *s*).	Calculated dielectric constant = D.	Temperature in platinum degrees.
Ethylic ether..	2·1	0·6	3·16	4·16	+15°
Glycerine	12·15	10·65	56·2	57·2	+30
Solution of ammonia (sp. gr. = 0·880)....	4·5	3·0	15·8	16·8	−123 (?)
	5·6	4·1	21·6	22·6	−137
	13·5	12·0	63·0	64·0	−119
Distilled water or pure ice ..	0·2	0·5	2·6	3·6	−49
	11·0	9·5	50·0	51·0	−7
	14·3	12·8	67·0	68·0	+1
Oxide of copper in suspension in water....	3·95	2·45	12·9	13·9	−61
	12·8	11·3	59·7	60·7	−41

The value found for the dielectric constant of water at +1° is rather low, but, as above mentioned, the smallness of the capacity of the experimental condenser prevented the results from being more than good indications of the *order* of the dielectric constant.

We have, in addition, repeated and extended experiments made with the cone condenser on various electrolytes and dielectrics.

In the first place, we have carefully examined the effect of change of temperature on the dimensions of the cone condenser *per se* to ascertain if the dimensional change produced by cooling it in liquid air could sensibly affect the value of the dielectric constant of an electrolyte forming the dielectric between the cones, apart from the change which temperature produces in the dielectric quality of the dielectric itself.

The gilt cone condenser was accordingly connected with the tuning-fork interrupter as formerly described,* and the galvanometer scale deflection when the condenser was charged with 97·2 volts was found to be 3·85 cm. to the left and 3·88 cm. to the right, hence the mean galvanometer deflection was 3·87 cm. of the scale. This corrected to 100 volts becomes 3·98, and deducting 0·4 cm. for the capacity of the leads, gives 3·58 as the number representing the electrical capacity of the cone condenser as then arranged. A standard condenser belonging to the Davy-Faraday laboratory, and having a capacity of one-thousandth of a microfarad, was then substituted for the cone condenser, and gave right and left deflections of 19·1 and 19·6 cm. respectively when charged with 97 volts. This corrected for capacity of leads (= 0·4 cm.) and reduced to 100 volts becomes 19·53. Hence, since the electrical capacities are proportional to the galvanometer deflection, the electrical capacity of our cone condenser is $\frac{3{\cdot}58}{19{\cdot}53} \times 0{\cdot}001$ of a microfarad, or 0·000183 of a microfarad.

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* See Fleming and Dewar, 'Roy. Soc. Proc.,' vol. 61, 1897, p. 299.

The capacity of the gilt cone condenser was then again measured with air at 20° C. as dielectric, and the galvanometer deflection observed. The outer cone was then cooled to −185° C. by quickly applying to it a large quantity of liquid air whilst the inner cone remained at about 20° C., and the galvanometer deflection again observed. This deflection was taken again when the inner cone had fallen in temperature to −75°, and finally when both inner and outer cones were at −185° C. The following numbers giving the galvanometer deflections are then proportional to the electrical capacity of the condenser between the cones.

Table V.—Examination of the Effect of Cooling on the Electrical Capacity of the Cone Condenser.

Galvanometer scale deflection in cm. or electrical capacity of the cone condenser in arbitrary units, the dielectric being gaseous air.	Remarks.
4·22 cm.	Both inner and outer cones both at 20° C.
4·82 cm.	Outer cone at −185° C. Inner cone at 20° C., about.
4·58 cm.	Outer cone at −185° C. Inner cone at −75° C.
4·19 cm.	Outer and inner cones both at −185° C.

Hence it is clear that mere change of temperature of the metal work of the cone condenser does not affect its electrical capacity by more than 1, or perhaps 2, per cent., and any larger changes in capacity found on cooling must be due to a real change in the dielectric constant of any dielectric substituted for the air between the cones, and not to mere dimensional changes of the condenser itself produced by the cooling.

Another matter to which our attention was directed was the question whether there was any sensible or serious lag in the temperature of the resistance thermometer behind the temperature of the dielectric. Our usual custom had been to immerse the condenser when prepared for use in liquid air, and cool down the whole mass to −185° C., and then raising it out of the liquid air to take temperature and capacity readings as it warmed up. The resistance thermometer was placed in the inner cone in a thin test-tube, and fixed in with fusible metal in the inner cone. We therefore tried one experiment with pure glycerine as dielectric, in which the electrical measurements were made as the condenser was slowly cooled, instead of being made as it slowly heated up. The process of cooling from −38° *pt.* to −201° *pt.* was allowed to occupy one hour and forty minutes. The values thus found for the dielectric constant for glycerine for this range of temperature were practically in agreement with those found when the condenser capacity was measured as it warmed up instead of cooled down.

Table VI.

I. *Dielectric Constant of Pure Glycerine.*

Corrected galvanometer deflection when the condenser had air as dielectric = 3·92 cm. for 100 volts.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−38·0	2·85	50·5	Condenser charged with 1·434 volts. Time = 3.5 P.M.
−42·6	2·97	52·8	
−46·0	3·00	53·3	
−55·8	3·17	56·5	
−64·8	3·03	53·8	Time = 4.15 P.M.
−98·8	2·70	3·95	Condenser charged with 17·0 volts.
−119·5	2·20	3·19	Time = 4.30 P.M.
−201·0	11·05	2·82	Condenser charged with 92·4 volts. Time = 4.45 P.M.

The above values of the dielectric constant of glycerine are in very fair agreement with the values obtained by us during rising temperature.*

We have also extended our former observations made with this cone condenser and the galvanometric method to certain other frozen electrolytes, and measured their dielectric constants at low temperatures.

The results and substances are as follows :—

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* 'Roy. Soc. Proc.,' vol. 61, p. 324.

II. *Dielectric Constant of Dry Concentrated Sulphuric Acid* (H_2SO_4).

The corrected galvanometer deflection with air as dielectric was 3·92 cm. for 100 volts. The switch frequency was 120.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−200·9	14·6	3·86	Condenser charged with 94·2 volts.
−186·0	14·8	3·90	,, ,, ,, ,,
−181·8	2·5	3·82	Condenser charged with 16·2 volts.
−150·7	2·7	4·13	,, ,, ,, ,,
−129·8	2·95	4·33	Condenser charged with 16·9 volts.
−110·0	6·0	7·25	Condenser charged with 17·0 volts.

III. *Dielectric Constant of Dry Concentrated Nitric Acid* (NO_3H).

Corrected galvanometer deflection with air as dielectric = 3·90 cm. for 100 volts.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−201·7	9·05	2·36	Condenser charged with 94·2 volts.
−182·7	9·27	2·46	
−165·8	9·25	2·42	
−118·2	9·40	2·45	
−129·7	10·00	2·62	

Before carrying out these experiments with the concentrated nitric and sulphuric acids the condenser had been carefully re-gilt and a glass steady-pin substituted for the ebonite one.

IV. *Dielectric Constant of Sodium Fluoride* (NaF).

(10 per cent. solution.)

Corrected galvanometer deflection with air as dielectric = 4·04 cm. for 100 volts.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−199·3	9·3	2·33	Condenser charged with 94·2 volts.
−174·2	9·3	2·35	
−149·2	10·35	2·55	
−135·0	14·35	3·67	
−125·0	19·6	5·05	
−115·7	4·4	7·07	Condenser charged with 15·2 volts.

The electrical resistance of the condenser at −200 *pt.* with frozen sodic fluoride as dielectric was 2000 megohms.

V. *Dielectric Constant of Hydrosodic Fluoride* (NaFHF).

(10 per cent. solution.)

Corrected galvanometer deflection with air as dielectric = 3·42 cm. for 100 volts.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−201·8	8·87	2·28	
−186·0	8·87	2·25	
−169·0	8·95	2·30	
−178·8	9·0	2·31	
−148·8	9·7	2·49	
−142·2	10·9	2·79	
−131·5	15·4	4·02	

VI. *Dielectric Constant of Sodium Peroxide* (Na_2O_2).

(5 per cent. solution.)

Corrected galvanometer deflection with air as dielectric = 4·41 cm. for 100 volts.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−198·0	4·5	71	Condenser charged with 1·434 volts.
−184·5	5·5	87	

VII. *Dielectric Constant of Solution of Hydroxyl* (H_2O_2).

(20 per cent. solution by volume.)

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
−203·5	10·8	2·38	Condenser charged with 99·2 volts.

Some experiments were then made by electrolysing freely certain electrolytes and freezing them with liquid air in the act of electrolysis. The dielectric constants were then subsequently determined in the frozen state.

VIII. *Dielectric Constants of Frozen Electrolytes, Electrolysed freely in the act of Freezing.*

Corrected galvanometer deflection with air as dielectric = 3·42 cm. for 100 volts.

Temperature in platinum degrees.	Mean galvanometer deflection in centimetres.	Dielectric constant.	Observations.
(*a*) 5 per cent. aqueous solution of potassic hydrate electrolysed with 0·2 ampere and 8 volts. Evolved gas = 5·1 c.c.			
−200·0	3·85	71·4	Condenser charged with 1·434 volts. Electrical resistance of condenser 5000 megohms when frozen.
(*b*) Water electrolysed with 1·0 ampere.			
−198·2	8·70	2·47	Condenser charged with 98 volts. Electrical resistance of condenser 5000 megohms when frozen.
(*c*) Water electrolysed with 2·1 amperes.			
−198·0	8·65	2·42	Condenser charged with 98·9 volts.

It is evident that the action of electrolysis prior to, and during freezing has no sensible effect on the subsequently measured dielectric constant even though the surfaces of the cone condenser are strongly polarised in the act of freezing the liquid dielectric.

We have then paid some attention to the possible cause of the high dielectric values of some substances at very low temperatures. It is clear from the above described experiments with the Nernst bridge that for organic bodies such as ethylic alcohol, amyl alcohol, ethylic ether, and glycerine we obtain practically the same dielectric values at the low temperature, both when they are measured by the galvanometric method with a switch frequency of 120, and when measured by Nernst's method with a frequency of 350, or about three times as great.

On the other hand for certain other bodies such as the frozen dilute hydrates of potassium and rubidium, and the oxide of copper suspended in ice, the dielectric value at the low temperatures is much diminished by increasing the frequency.

Subsequently to the completion of the experiments described in this paper the suggestion has been made by R. Abegg* that the high dielectric values at low temperatures are due to polarization of the electrodes of the condenser, and that the capacity measured is a polarisation capacity and not a true dielectric capacity, and he supports this contention by pointing out that whenever we have obtained a large dielectric value at the low temperature it has always been measured with an electromotive force of 1·434 volts, which is less than the ordinary full reverse electromotive force of polarization.

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* 'Wied. Ann.,' vol. 62, p. 249.

There are, however, reasons for considering that this contention is not a valid one. In the first place we have always in all the measurements begun operations by testing the dielectric capacity of our condenser with an electromotive force of one Clark cell (= 1·434 volts) in order to see roughly whether the dielectric value was large or small. If it was a small value we then gradually increased the electromotive force until a good readable galvanometer deflection was obtained. We never found that with an electromotive force of 1·434 volts, the dielectric constant of any substance was greater than with a much higher voltage.

In the next place, in many cases we changed from a working electromotive force of about 20 volts to one of 1·434 volts, and we never found any marked discontinuity in the calculated value of the dielectric constant at that point. If our previous papers on this subject are examined the following instances may be found.

Table VII.—Measurement of various Dielectric Constants with different Electromotive Forces.

Substance.	Temperature.	Dielectric. constant.	Voltage with which constant was measured.	Reference.
Ice	− 89·4	27·6	19·8	'Roy. Soc. Proc.,' vol. 61, p. 318.
	− 87·2	29·0	1·4	
,, ...	−124·2	18·1	20·3	*Ibid.*, p. 321.
	−119·2	21·8	1·4	
Sodic chloride, 10 p. c. solution..	−118·5	21·2	20·2	*Ibid.*, p. 307.
	−114·0	22·3	1·4	
Potassic chromate, 30 p. c. solution..	−112·4	16·9	20·0	*Ibid.*, p. 387.
	−100·0	22·3	1·4	
Cupric carbonate, 10 p.c. suspension	−124·7	16·5	18·2	*Ibid.*, p. 390.
	−120·8	21·8	1·4	
Baric hydrate, 5 p. c. suspension	−178·0	23·9	19·5	*Ibid.*, p. 372.
	−174·2	25·5	1·4	
Bismuth oxide, 10 p.c. suspension	−129·2	19·9	17·8	*Ibid.*, p. 376.
	−127·3	24·5	1·4	

An examination of the above instances will show that if the electromotive force is changed from about 20 volts to 1·4 volts, it does not make a greater difference in dielectric constant than can be properly ascribed to the accompanying change in temperature.

[Again the following measurements were made at about the same voltage :—

Substance.	Temperature.	Dielectric constant.	Charging voltage.
Potassic Bicarbonate ...	−166·5	2·80	19·8
Sodic Bicarbonate	−166·7	48·70	19·8
Ferric Chloride........	−133·8	4·23	19·8
Sodic Chloride.........	−129·2	14·55	20·2
Cupric Carbonate	−132·7	3·42	18·2
Cupric Sulphate	−133·2	16·40	19·7
Lithic Hydrate	−198·0	3·23	19·8
Baric Hydrate	−196·8	20·10	19·5

It is unlikely that polarisation accounts for the differences between the dielectric constants of the above substances, taken pair and pair, when measured at nearly identical temperatures, and very nearly the same voltages.—*November* 8, 1897.]

In order to settle the matter finally we propose, however, to remeasure a number of those substances which have shown high dielectric values at the low temperature when measured by the galvanometric method at a frequency of 120 but using in all cases an electromotive force of 100 volts.

If under the larger electromotive force the dielectric values of some electrolytes still remain large, it will be difficult to ascribe this large value to polarization.

The facts, however, admit of another interpretation. It is clear that the dielectric constants of some substances at low temperatures are vastly more susceptible to change of electromotive force frequency than is the case with others, and that the electric strain produced by a given electric stress varies in some cases enormously with the time of imposition of the stress but very little in others.

Another argument against the view that these high dielectric values are due to polarisation, as ordinarily understood, is as follows: The results of most numerous experiments on water show that the dielectric constant at or near 0° C., is a number not far from 80. This value is obtained whether the electromotive force reversals are infinitely slow or whether they are very large. The results of the measurement of the electrical refractive index of water even with ether waves only 4 mm. in length, and, therefore, having a frequency of about $7·5 \times 10^{10}$, as given recently by Lampa,* indicate a number not far from 9·5 as the refractive index and hence give a dielectric value of 90. There can be no question of polarisation of electrodes in this last case. On the other hand an increase in frequency which hardly affects the value of the dielectric constant of water is sufficient to greatly decrease that of ethylic alcohol, and at the same frequency the dielectric constant of ethylic alcohol was found by Lampa to have fallen to a value of 5. Hence ethylic alcohol is more sensitive to change of frequency than water. There is, therefore, no *a priori* reason why we might not expect to find the same thing even in a much greater degree in certain other bodies at lower temperatures, viz., a true high dielectric value for a certain frequency, but great sensitiveness to increase of frequency in such fashion that increase of frequency greatly reduces the dielectric value. At the present stage of the enquiry it seems undesirable to endeavour to regard the facts wholly from the point of view of one hypothesis as to the nature of electrolysis.

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* 'Wien. Ber.,' Part 2*a*, p. 587, 1896; also p. 1049, 1897.

We have again to mention with pleasure the assistance we continue to receive from Mr. J. E. Petavel in the observational part of these investigations.

Note added December 8, 1897. Received December 9, 1897.

Since the above paper was printed we have repeated some of our former experiments with the 5 per cent. solution of rubidic hydrate and the 5 per cent. solution of potassic hydrate, using the original method in which a condenser having the frozen electrolyte as dielectric is charged and discharged through a galvanometer, but employing much higher charging voltages. The object of these experiments was to apply a further test as to the validity of the contention put forward by R. Abegg, that we have obtained high dielectric values for certain of these frozen electrolytes in consequence of having invariably used an electromotive force of 1·434 volts in the experiments with these particular substances. In order to be able to work with larger electromotive forces we arranged three galvanometers of the Holden d'Arsonval type otherwise exactly similar, except in having different sensibilities and resistances. One was the 500-ohm galvanometer used in all our previous condenser experiments, another was a 100-ohm coil galvanometer, and a third was a 4-ohm coil galvanometer. These were used at the same distance (125 cm.) from the scale as formerly. An approximate test for the relative sensibility of these galvanometers was made by placing a Clark standard cell in series with each galvanometer through 100,000 ohms and noting the scale deflection produced. As the internal resistance of the galvanometers was at most only $\frac{1}{2}$ per cent. of the total resistance these scale deflections may be considered to be approximately produced by the same current. The scale deflections in centimetres were—

For the 500-ohm galvanometer....	37·3 cm.
" 100-ohm "	6·7 "
" 4-ohm "	0·55 "

Hence, the sensibilities are in the ratios of these deflections, and the deflections of the 100-ohm galvanometer must be multiplied by 5·5, and those of the 4-ohm galvanometer by 67·8, to reduce their scale readings to equivalent deflections in terms of the 500-ohm galvanometer.

The 500-ohm galvanometer was then used with the condenser and vibrator, as described in one of our previous papers.* The condenser having gaseous air as dielectric, the scale deflection for a frequency of 120 and an electromotive force of 97 volts was 3·2 cm. when corrected for capacity of leads.

The condenser then had its dielectric space filled with the 5 per cent. solution of rubidic hydrate, and was frozen in liquid air. The dielectric constant was next measured, using an electromotive force of 17·8 volts and the 500-ohm galvanometer. The value of the dielectric constant found, when corrected for the capacity of the leads, was 65·6. The mean corrected scale deflection was 38·5 cm. for 17·8 volts. This, reduced to its equivalent for 97 volts, is 210 cm. and 210/3·2 = 65·6.

In the next place the same experiment was repeated employing the 100-ohm galvanometer and an electromotive force of 79 volts. Applying the necessary corrections to the observed scale deflection of 23·5 cm., and reducing to the equivalent deflection on the 500-ohm galvanometer, gave 160 cm. as the value of the reduced deflection. Hence 160/3·2 = 50 is the dielectric constant. The rather considerable difference between these values (65·6 and 50) is not a matter for surprise, having regard to the extreme steepness of the dielectric curve of the rubidic hydrate solution at about the temperature of liquid air. As we were merely desirous of determining whether a considerable increase of electromotive force would greatly diminish the large dielectric value, we did not trouble to put in operation the rather elaborate platinum thermometer arrangements for determining the exact temperature of the dielectric. A reference to the dielectric-temperature curve of rubidium hydrate† will show that even one or two degrees of temperature change in the neighbourhood of −185° C., or −200° pt. makes a very considerable alteration in the dielectric value. The result, however, ascertained is that changing the electromotive force from 1·434 volts to 17·8 or 79 volts does not bring down the dielectric constant from a large value to a small one.

In the same way the 5 per cent. solution of potassic hydrate was tested.

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* 'Roy. Soc. Proc.,' vol. 61, p. 300, 1897.

† *Ibid.*, p. 378.

Using the 500-ohm galvanometer and an electromotive force of 9·88 volts we found 153 as the dielectric constant of the frozen electrolyte at the temperature of liquid air. Employing the 4-ohm galvanometer and 79·5 volts we found 175 as the dielectric constant.

All the above observations were taken at the temperature of liquid air and with an electromotive force frequency of 120. It is, therefore, quite clear that as far as these two frozen electrolytes are concerned, raising the charging voltage to a value far above that of the average electromotive force of polarisation does not bring down these abnormal values of the dielectric constant. On the other hand, a relatively small decrease in the temperature or *increase in the frequency at low temperatures* suffices to reduce the dielectric value of these frozen hydrates very considerably.* We may, therefore, say that the contention put forward by R. Abegg that the high dielectric values we have found for certain substances at the liquid air temperature are really polarisation capacities, does not seem to be borne out by the results of further experiment, and for the following reasons :—

(i) Because a very great increase in the charging electromotive force does not in any corresponding degree reduce the abnormally high dielectric values of certain frozen electrolytes to much smaller values.

(ii) Because when in the course of observations to construct a temperature dielectric curve, the working electromotive force has been changed from a value below the counter-electromotive force of polarisation to a value far above it, there is no break or discontinuity in the curve of dielectric value.

(iii) Because the great difference between quite similar electrolytes, such as the 10 per cent. solution of potassic and sodic carbonates, in respect of dielectric constant at equally low temperatures and under equal charging electromotive forces is left unexplained.

(iv) Because in the case of many substances, such as frozen ammonic hydrate, ice, and oxide of copper in suspension in ice, at very low temperatures, we find high dielectric values even though employing alternating currents of fairly high frequency (350 ∼).

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* The effect of increased frequency of electromotive force reversals in decreasing the dielectric constant is evidently dependent upon the temperature as well as on the physical state of the body. In the case of water an increase in the frequency from zero to 10^6 hardly affects the dielectric constant at all. In the case of ice at 0°C. the same increase in frequency reduces the dielectric constant from 80 to between 2 and 3. In the case of ice at -50° C., as we have shown above, an increase in frequency from 120 to 350 reduces the dielectric constant from about 60 to about 3·6. (December 21, 1897.)

(v) Because the high dielectric values of water and alcohol and other bodies at ordinary temperatures remain, even when the observations are taken with alternating electromotive forces of exceedingly high frequency and under conditions when there are no electrodes to polarise, as when the electric refractive index is measured with electromagnetic radiation.

We consider that the results of observations so far made are best expressed by merely considering the dielectric constant to be a function of the frequency and the temperature, and represented therefore by a *dielectric surface*, which surface has for some substances a region of abnormal dielectric ordinate.

In all cases so far examined by us, lowering the temperature sufficiently acts in the same manner in reducing the dielectric constant as sufficiently increasing the frequency, and both actions reduce the abnormally large dielectric values of some substances to values more approximately equal to the square of the optical refractive index of the body.

The question then to be considered is the physical reason for the high dielectric values for particular substances for certain ranges of electromotive force frequency and temperature. Whether this abnormal electric displacement is considered to be the result of a molecular strain superimposed on a true electric strain, or whether it is the beginnings of that molecular deformation which finally ends in chemical decomposition, remains to be seen. Having regard to the enormously high electrical resistivity which we have shown these frozen dielectrics to possess, it does not appear to us likely that polarisation in the sense of a deposition of ions on the electrodes can be invoked to explain the differences we have shown exist.